Scalping Reduces Impact of Soilborne Pests and Improves Survival and Growth of Slash Pine Seedlings on Converted Agricultural Croplands

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ABSTRACT. *Field studies in northern Florida over 2 yr confirmed an association between certain soilborne agricultural pests and the first-year failure of slash pines (*Pinus elliottii *Engelm. var.* elliottii*) on recently converted agricultural croplands. Whitefringed beetles (*Graphognathus *spp.) and the charcoal root rot fungus (*Macrophomina phaseolina *[Tassi] Goid.), were associated, respectively, with up to 99 and 30% of the seedling mortality in individual study fields. Whitefringed beetles were the dominant pests in Florida's western panhandle, but* M. phaseolina *assumed an apparently more important role in the more drought-vulnerable sands of north-central Florida. The involvement of other soilborne insects, fungi, and plant parasitic nematodes appeared less important, but is not dismissed. Prescriptive treatments including carbofuran and benomyl root dips, soil-incorporated diazinon insecticide, methyl bromide soil fumigation, topically applied chlorpyrifos insecticide, band applications of sulfometuron and atrazine herbicides, and scalping varied in efficacy with respect to reducing pest damage and improving seedling performance. With the exception of one instance where seedlings grown in methyl bromide-treated soil performed best, seedlings in scalped rows consistently survived and grew better than seedlings in all other treatments. Across five study sites, seedlings in scalped rows averaged 83% survival, 54 cm in height, and 1.0 cm in groundline stem diameter after 1 growing season. Seedlings in check rows were among the poorest performers, averaging only 62% survival, 46 cm in height, and 0.8 cm in groundline stem diameter. Herbicide-treated seedlings performed similarly, averaging 60% survival, 46 cm in height, and 0.9 cm in groundline stem diameter. South. J. Appl. For. 19(2): 49–59.*

The nation's Conservation Reserve Program (CRP) has resulted in the planting of some 890,300 ha of erodible agricultural croplands to trees (Bjerke 1991) since its inception in 1985. Approximately 768,900 ha (86%) of this total has been planted (predominantly to *Pinus* spp.) in the Southeast alone. In Florida, qualifying cropland planted to pines (predominantly slash pine, *Pinus elliottii* Engelm. var. *elliottii*) under the CRP totals approximately 45,300 ha.

While these figures are impressive, and the CRP has been touted as possibly "the nation's largest, most successful, single tree planting program in history" (West 1988), excessive first-year seedling mortality occurred in many CRP plantations in several southern states (Steinbeck 1990, Mitchell et al. 1991, Cordell et al. 1993). In 1987, widespread plantation failure in CRP plantings in Florida prompted field evaluations which identified a consistent association between seedling mortality and certain fungal and insect pests. Predominant among these pests were the charcoal root rot fungus (*Macrophomina phaseolina* [Tassi] Goid.) (MP), the pitch canker fungus (*Fusarium subglutinans* (Wollenw. & Reinking) Nelson, Toussoun & Marasas) (FS), other pathogenic *Fusarium* spp. (esp. *F. oxysporum* (Mart.) Sacc. and *F.*

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solani Schlechtend.: Fr.), and root-feeding insects, including whitefringed beetles, *Graphognathus* spp. (WFB) and white grubs, *Phyllophaga* spp. (WG) (authors, unpublished). Similar observations were made by forest pest management specialists in other southeastern states (Andrew Boone, South Carolina For. Comm. and Terry Price, Georgia For. Comm., pers. comm.). In 1988, a survey (Cordell et al. 1993) was conducted to assess the southern regional distribution and impact of CRP plantation failures, and to determine the association of suspect and/or potential fungal and insect pests. At the same time, we initiated a study on recently converted agricultural croplands in Florida to (1) systematically evaluate relationships between specific fungal and insect pests and slash pine seedling mortality and (2) assess the efficacy of certain pest management strategies in reducing pest activity and improving pine seedling performance (survival and growth) on such sites.

Materials and Methods

Site Selection and Experimental Design

Study sites were selected in 1988 and 1989 based on their histories of pine plantation failure (at least 2 yr) and observed presence of fungal (MP and *Fusarium* spp.) and insect (WFB and WG) pests. Each site was cleared by mowing in the fall (October–November) prior to establishment of study plantations in January of the subsequent calendar years. Two slash pine plantations were established in 1989 (Okaloosa and Madison counties) and three were established in January 1990 (Okaloosa, Holmes, and Madison counties). Eight treatments (Table 1) were evaluated on each study site for their effects on the impact of certain soilborne pests and first-year seedling performance (i.e., survival and growth). Seedlings were machine planted by treatment in 70 (1989) or 75 (1990) tree row plots on each site in a randomized complete block design with five replications. Rows were 3 m apart and seedlings were spaced at 1.5–1.8 m intervals within rows; each study plantation therefore covered approximately 2 ha.

Preplant Assessments of Soilborne Pest Populations

Assessments of soilborne populations of MP, *Fusarium* spp., plant parasitic nematodes, WFB and WG were conducted in the fall–early winter immediately preceding January establishment of individual study plantations. MP assays were performed on check, methyl bromide-treated, and scalped plots, whereas WFB and WG assays were conducted on check soils only. Assays for *Fusarium* spp. were conducted on check soils only, and only prior to the 1989 plantation study year on the Okaloosa and Madison county sites. Nematological assays were performed on check and methyl bromide-treated plots prior to the first study year (1989) and check and scalped plots prior to the second study year (1990).

Soil samples for fungus and nematode assays were collected, placed in plastic bags, and carried in an ice chest to the laboratory for processing. Each soil sample consisted of a composite of ten 2.5 × 15 cm soil cores. Cores for each composite were collected around each of four foci linearly distributed at 23 m intervals along sampled treatment plots in each of the five replicate blocks (4 foci × 5 replicates = 20 composite samples per treatment per site). In the laboratory, samples were thoroughly mixed and subsequently divided three ways for MP, *Fusarium*, and nematode assays.

Soil subsamples for MP population estimates were dried overnight in a plywood box equipped with incandescent bulbs (ca. 38-40°C) and then passed through a 2 mm sieve (U.S. Std. No. 10). Two-gram subsamples of sieved soil were

Table 1. Description of treatments evaluated for improving survival and growth of nursery-run slash pine seedlings planted on recently converted agricultural croplands in northern Florida.

Treatment (CODE)	Description
	Seedlings planted with no special site preparation except mowing in October prior to January planting.
	Soil mechanically scalped ("scalping" consisted of sod/stubble and soil removal with a tractor-drawn plow blade, ca. 0.75 m wide and 7.5–10 cm deep). Plots scalped in November–December prior to January planting.
Herbicide (HERB)	Seedlings treated in April with an over-the-top band application of Oust® and Dupont Atrazine® herbicides @ 210 gr and 3.4 kg per treated ha, respectively.
Diazinon (DIAZ)	Soil treated in December with 23.5 kg/ha Diazinon® 14G insecticide (insecticide disked into soil following broadcast).
Chlorpyrifos (CHLOR)	Seedlings band-treated in April with Lorsban® 15G insecticide @ 14.5 kg/ha.
Carbofuran (CARBO)	Seedling roots dipped in a 1% a.i. (W/V) Furadan® 4F/kaolin clay slurry and planted without special site preparation.
Methyl Bromide (MB)	Soil fumigated in October with methyl bromide-chloropicrin soil fumigant (66 and 33% a.i., respectively) @ 392 kg/ha.
Nursery-2 (NSY2)	Seedlings from another nursery planted with no special site preparation except mowing in October prior to January planting.
1990 study plots	Check, Scalp, Herbicide, Diazinon, Carbofuran, and Nursery-2 treatments applied/installed as per 1989 protocol. Chlorpyrifos and Methyl Bromide treatments dropped. Benomyl and Disk treatments were applied/installed as follows.
Benomyl (BEN)	Seedling roots dipped in a 2.5% a.i. Benlate® 50 WP/kaolin clay slurry (380 gm clay + 20 gm Benlate® 50 WP/l H2O; after J. P. Barnett) and planted with no special site preparation except mowing in October prior to January planting.
Disk (DISK)	Soils disked in December in the same manner as those receiving diazinon insecticide (ref. 1989 plots — above), but without Diazinon® 14 G.

then processed as described by McCain and Smith (1972). Cultures (5 Petri dishes per 2-gm subsample) were incubated in the dark at 31°C for 7–14 days as needed and counts of individual colonies of MP were performed. Populations of MP were expressed as colony-forming units (CFU) per gram of dried soil.

Soil subsamples for analysis of *Fusarium* spp. were air-dried at ambient laboratory temperatures (25±2°C) and passed through an 850 µ sieve (U.S. Std. No. 20). One-gram subsamples of sieved soil were then suspended in sterile deionized water at a ratio of 1:500 (W:V) and 1 ml aliquots of these suspensions were plated onto each of three replicate plates of a modified *Fusarium*-selective medium (Nash and Snyder 1962). Colonies of *Fusarium* spp. were counted after 7 days incubation under ambient laboratory conditions and representative colony types were subcultured and identified using the keys of Nelson et al. (1983). Populations of *Fusarium* spp. were expressed as CFU per gram of air dried soil.

Soil subsamples for nematode population assessments were subjected to standard extraction procedures (Jenkins 1964). Procedures were performed by the Bureau of Nematology at the Florida Department of Agriculture and Consumer Service's Division of Plant Industry in Gainesville. Populations of plant parasitic nematodes were expressed as numbers of nematodes per 100 cc of soil.

Preplant soilborne insect populations were conducted by digging holes (ca. 30 × 30 × 15 cm deep) at 20 locations systematically distributed across each planting site (4 locations at 23 m intervals × 5 replicates = 20 locations per site). Soil from each hole was sieved and/or sorted manually and examined for larvae of WFB (Figure 1B), WG, and other insects.

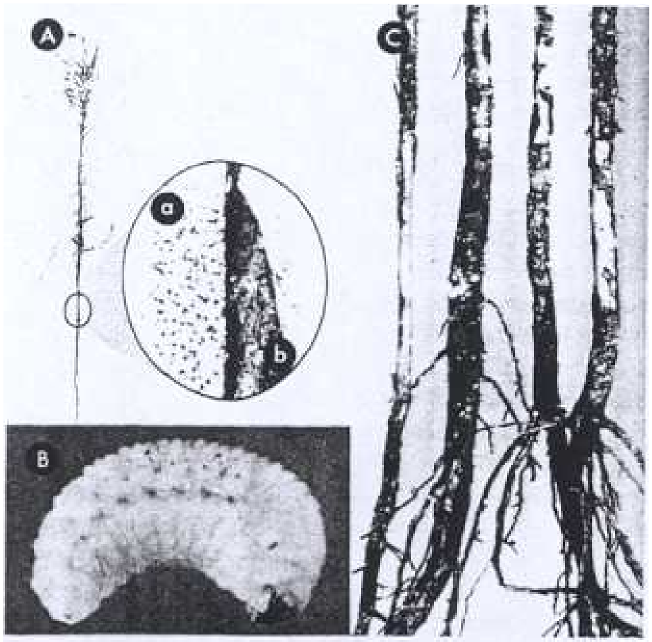

Figure 1. (A) Microsclerotia of *Macrophomina Phaseolina* as seen with a hand lens beneath the bark at the root collar of a dead slash pine (a—on xylem surface; b—underside of bark). (B) Larva of whitefringed beetle (mature size = ca. 12 mm). (C) Feeding damage (i.e., decortication) caused by whitefringed beetle larvae.

Seedling Survival and Growth Assessment

Study plantations were visited at approximately monthly intervals beginning in March or April and continuing through December of their respective planting years. On each visit, all dead and dying seedlings were carefully removed from the soil with a shovel, placed in labeled plastic bags, and carried in ice chests to the laboratory for analysis. Cumulative survival/mortality data were employed to generate first-year survival curves for seedlings by treatment on each site. First-year growth of surviving seedlings within each treatment on each site was assessed in December of the years in which seedlings were planted. Height was measured to the nearest cm on the first 25 live seedlings within each row plot. Groundline stem diameters were measured to the nearest mm on the first 10 surviving seedlings in each plot. Mean survival, height, and stem diameter data were incorporated into a plot volume index (PVI) for each treatment (Marx et al. 1984).

Laboratory Analysis of Seedlings

In the laboratory, all dead and dying seedlings were individually examined macroscopically for evidence of insect feeding damage, e.g., roots severed, roots and lower stems decorticated (Figure 1C) (Filer et al. 1977, Dixon 1988, Price 1988), and with the aid of a 10× hand lens or a stereo microscope as necessary for the presence of microsclerotia of MP beneath the bark of roots and lower stems (Figure 1A). Seedlings were also examined for resin-soaking characteristic of pitch canker infections (Barnard and Blakeslee 1980).

Isolations were performed from dead and dying seedlings collected in 1989 only. A 1 cm stem segment at or near the root collar and four 1-2 cm segments of necrotic lateral or feeder roots were excised from each seedling, soaked for 3 minutes in 0.5% sodium hypochlorite, rinsed in sterile deionized water, placed on acidified (3.3 ml of 50% lactic acid/liter) potato dextrose agar, and incubated at ambient laboratory conditions for 7-10 days. Records were maintained on the frequency of recovery of MP, *Fusarium* spp., and other potentially important fungi.

Statistical Analyses

Data from MP population estimates and seedling survival and growth assessments were subjected to analysis of variance (ANOVA) through MINITAB's Release 7.2® data analysis software (MINITAB, Inc. 1989). Treatment means within individual study plantations were compared at $P \geq 0.05$ using Duncan's new multiple range test (Steel and Torrie 1960).

Results

Preplant Assessment of Soilborne Pest Populations

MP was abundant in all study site soils with population estimates in untreated soils ranging from 6.4 to 13.4 CFU per gram of dry soil (Figure 2). In the 1989 plantings, no MP (or nematodes—data not presented) were recovered from methyl bromide (MB)-treated soils on the Madison Co. site. On the Okaloosa Co. site, the effects of MB treatment were variable among replicates. Scalping significantly ($P \geq 0.05$)

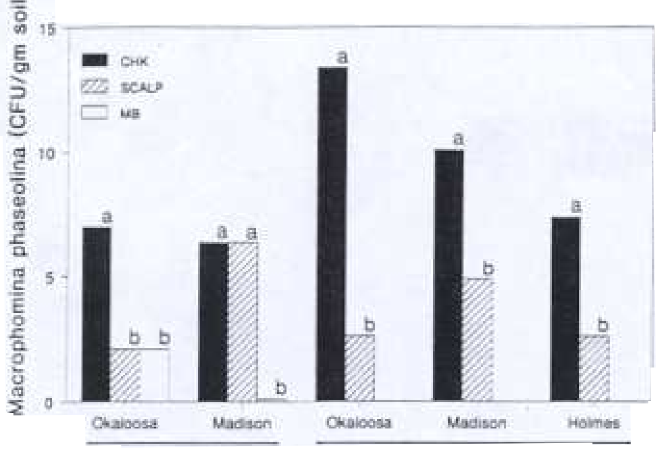

Figure 2. Relative populations of *Macrophomina phaseolina* by treatment in colony-forming units (CFU) per gram air-dried soil on converted agricultural croplands in northern Florida prior to establishment of slash pine study plantations. Within a given site and year, populations depicted by bars with different letters differ significantly at $P \geq 0.05$. (Methyl bromide applied to 1989 sites only.)

reduced rhizosphere populations of MP on four of the five study sites evaluated in the 2-yr study.

Fusarium spp. were detected in soil from both 1989 study sites at levels of approximately 2000 CFU/gram of dried soil (total: all *Fusarium* spp.). Only *F. solani* and *F. oxysporum* were isolated from the Madison Co. site. These two species and *F. lateritium* Nees, *F. moniliforme* Sheldon and *F. semitectum* Berk. & Rav. were isolated from the Okaloosa Co. site. FS was not detected in soil from either site.

Six genera of plant-parasitic nematodes (ring = *Criconemella*, spiral = *Helicotylenchus*, root-knot = *Meloidogyne*, lesion = *Pratylenchus*, stubby-root = *Trichodorus*, and dagger = *Xiphinema*) were recovered from soil at the Okaloosa Co. site in numbers ranging from 1 to 73/100 cc of soil. Four of these genera (*Criconemella, Helicotylenchus, Pratylenchus* and *Xiphinema*) were recovered from soil at the Holmes Co. site at comparable levels, but only three (*Criconemella, Pratylenchus,* and *Xiphinema*) were recovered from soil at the Madison Co. site. Counts of *Xiphinema* spp. and *Criconemella* spp., however, were notably higher in Madison Co., averaging 55 and 1470 per 100 cc of soil, respectively.

Sites in Okaloosa and Holmes Counties (Florida's western panhandle) supported greater numbers of WFB larvae than did sites in Madison Co. (north-central Florida). WFB larvae were not detected during the Madison Co. site assessments, although small numbers were observed later when seedlings were sampled. In contrast, 3, 56, and 28 WFB larvae were counted in soil samples from the Okaloosa (1989, 1990) and Holmes (1990) Co. sites, respectively. White grubs were detected in low numbers (1–10 per site) in soil from all five sites with no consistent site or geographical differences.

Seedling Survival and Growth Assessment

Seedling survival by treatment through the first growing season is depicted in Figure 3. Year-end survival and growth measurements are presented in Table 2. Certain trends are clear. Seedlings planted in scalped (SCALP) rows generally outperformed those in all other treatments, whereas check (CHK) and herbicide (HERB)-treated seedlings were consistently among the poorest performers in all five plantations. As expected, seedlings in methyl bromide (MB) treated soils (1989) performed very well. Performance of seedlings within other treatments varied among sites and between planting years. For example, Nursery-2 (NSY2) seedlings performed relatively well in 1989, but did poorly on two of the three sites in 1990. Chlorpyrifos (CHLOR) had no beneficial effect on seedling performance. Diazinon (DIAZ) and disking (DISK) treatments showed variable, but recognizable benefits in some cases. In 1989, carbofuran (CARBO) treated seedlings were among the best performers on the Okaloosa Co. site, but were relatively unimpressive in Madison Co. In 1990, benomyl (BEN) and CARBO treated seedlings exhibited very good survival in Madison Co., but this good survival was not accompanied by good growth. In Okaloosa Co. (1990), early survival of CARBO treated seedlings was comparatively good, but survival of these seedlings declined rapidly after June. Seedlings in all treatments showed good survival and growth in Holmes Co. (1990), but herbicide-treated seedlings still performed significantly poorer than those of all other treatments on this site ($P \geq 0.05$).

Laboratory Analysis of Seedlings

A total of 1775 dead and dying root systems from the 1989 plantations (781—Okaloosa, 994—Madison) were examined. Consequently, 8,875 root segments were isolated onto Petri dishes. *Fusarium oxysporum* was isolated from the majority of the root systems (both sites), whereas *F. solani* was isolated relatively infrequently. FS was isolated very infrequently, and typically only from resin-soaked root or stem lesions. MP was isolated from 3.7 and 17.4% of the seedlings (all treatments) from the Okaloosa and Madison Co. sites, respectively. Interestingly, visual detection of MP microsclerotia on root systems evaluated in 1989 was equally as effective as isolation recovery in confirming the presence of MP. The fungus was observed on 3.6 and 17.2% of the seedlings examined from Okaloosa and Madison counties, respectively. However, the total numbers of seedlings on which MP was confirmed, accounting for both visual and cultural positives, were considerably higher than those confirmed by either method alone, 6.8% in Okaloosa Co. and 24.9% in Madison Co. Although important differences among treatments were not apparent in Okaloosa Co., the lowest proportions of dead and dying seedlings with MP in Madison Co. occurred in SCALP and MB treated plots, 15 and 7%, respectively, as compared to 20-51% ($\bar{x}$ = 30.8%) for all other treatments. Root/stem resin-soaking was observed in only 5.5 and 5.1% of the seedlings from Okaloosa and Madison Counties, respectively; differences among treatments were not outstanding.

In Okaloosa Co., an average of 53.1% of the seedlings examined in 1989 (all treatments) exhibited insect feeding injury typical of that caused by WFB larvae. Only 30 and 42% of the seedlings from MB and SCALP plots, respectively,

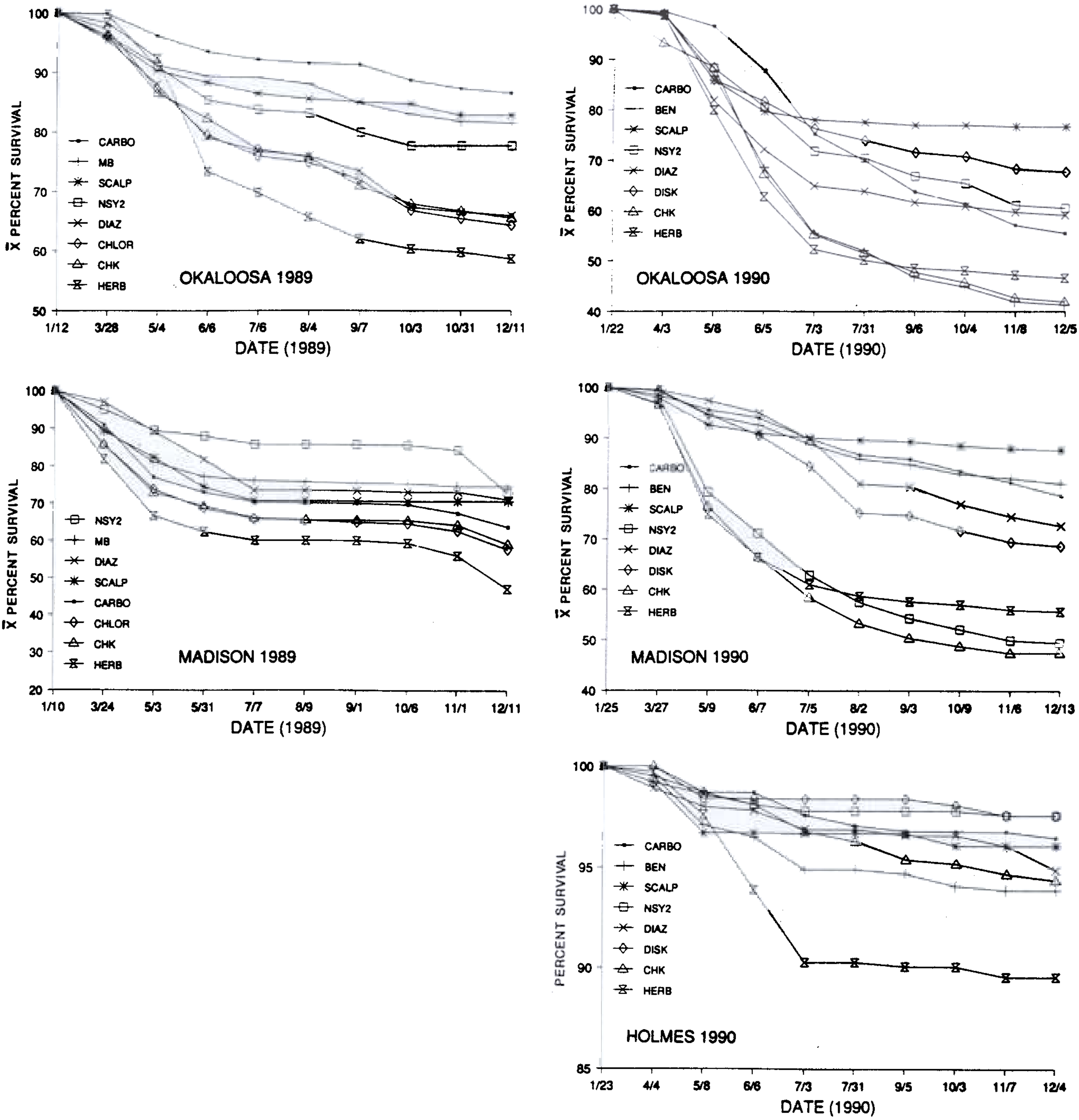

Figure 3. Survival by treatment of slash pine seedlings over time on converted agricultural croplands in northern Florida.

displayed this damage, whereas between 53 and 67% ($\bar{x}$ = 58.8%) of those in all other treatments were so damaged. In Madison Co., insect feeding damage was observed on only 10% of the dead and dying seedlings examined (average, all treatments), with the lowest incidence occurring in CARBO (3%) and MB (7%) plots.

In 1990, a total of 2419 dead and dying seedling root systems (1306—Okaloosa, 146—Holmes, 965—Madison) were visually evaluated. MP was detected on 5.5, 7.4, and 28.1% of the seedlings (average, all treatments) from Okaloosa, Holmes, and Madison counties, respectively. Seedlings from SCALP and BEN-treated plots consistently displayed the lowest proportions of MP-positive seedlings, 1 and 2, 0 and 4, and 15 and 6% in each of the three counties, respectively. In contrast, the fungus was detected on from 4–11% ($\bar{x}$ = 6.8%), 0-26% ($\bar{x}$ = 9.2%), and 30–37% ($\bar{x}$ = 34.0%) of the seedlings examined from all other treatments in the three counties, respectively. Root or stem resin-soaking was detected on 6.1 and 6.2% of the seedlings from Okaloosa and Holmes Counties, respectively, and from only 4.2% of those from Madison Co. Differences among treatments were not outstanding, but BEN-treated trees consistently exhibited the lowest levels of resin-soaking, 2, 0, and 1% on the three sites, respectively.

Insect feeding damage was detected on 98.6% of the seedlings examined in 1990 from Okaloosa Co., 64.5% of

Table 2. First-year survival and growth of slash pine seedlings as affected by silvicultural treatments on recently converted agricultural croplands in northern Florida[1].

Treatment[2]	Mean survival (%)	Mean height (cm)	Mean root-collar diameter (cm)	Mean PVI (cm^3)[3]
	84ab	60a	1.3a	6621a
	82bc	59a	1.2ab	5353ab
	86a	53b	1.0ab	3388b
	66d	57a	1.1ab	3757b
	64d	51c	1.1ab	3142b
	59e	45d	1.1ab	2359b
	78c	53b	1.1ab	3552b
	65d	51bc	1.0b	2519b
	71a	49b	0.9ab	1978bc
	75a	51ab	1.2a	3973a
	64b	41e	0.7b	847e
	71a	48bc	0.9b	1908c
	58c	45cd	0.8b	1048e
	47d	52a	1.0a	1591c
	73a	53a	0.9b	2198b
	58c	44d	0.7b	946e
	77a	54a	1.0a	3039a
	41f	44d	0.7a	621d
	55d	49b	0.7a	1199c
	59e	49bc	0.8a	1607b
	68b	50b	0.8a	1650b
	47e	46cd	0.8a	1070c
	61c	41e	0.7a	969c
	42f	48bc	0.7a	995c
	96a	60a	1.0a	4706a
	94b	55bc	1.0a	3741c
	97a	62a	1.0a	4370b
	95a	56b	0.8a	2861d
	98a	59a	1.0a	4029b
	90c	48d	0.9a	2577de
	98a	53c	1.0a	3559c
	94ab	54bc	0.8a	2399e
	88a	46a	1.1a	3747a
	81b	38d	0.7b	1045c
	79b	38cd	0.7b	1085c
	73c	42b	0.9ab	2085a
	69d	42bc	0.8ab	1486b
	56e	41bc	0.9ab	1094c
	50f	34e	0.7b	633c
	47f	35e	0.8ab	724c

[1] Within column means for each planting sharing a common letter do not differ significantly @ $P \leq 0.05$.
[2] See Table 1.
[3] Plot Volume Index (PVI) = (mean height × (mean root-collar diameter)^2 × (mean no. surviving seedlings/plot). Note: PVIs shown in table were calculated from plot data for statistical analysis, not the treatment means indicated in colums 2–4. Due to rounding, squaring, etc., PVIs calculated from data in colums 2–4 will differ.

those from Holmes Co., and 26.4% of those from Madison Co. Damage observed on seedlings from Okaloosa and Holmes counties was consistently typical of that caused by WFB larvae. In Madison Co. the damage was mixed; many seedlings exhibited lateral root severance only, and root or stem decortication was often less severe than that observed in Okaloosa and Holmes counties.

A summary of the number of dead and dying seedlings removed from check plots over time and the associated incidence of MP, root or stem resin-soaking, and insect feeding damage for all sites is presented in Figure 4. The average number of seedlings removed from each plot by treatment through the first growing season, together with the associated incidence of the respective pests or pest indicators, is depicted in Figure 5.

Discussion

Populations of soilborne fungal and insect pests often increase where susceptible and/or preferred host crops are grown, especially if they are grown in successive years without adequate controls (Young et al. 1950, Watanabe et al. 1970, Meyer et al. 1973, Conner 1988, Leslie et al. 1990). Populations of both MP and WFB are favored by certain leguminous and other row crops including soybeans, peanuts, and cotton (Young et al. 1950, Watanabe et al. 1970, Watkins 1981, McDonald and Mehan 1984, Wylie 1989). Results of our study and related field investigations (authors—unpublished) substantiate variable, but distinct, relationships between these soilborne agricultural pests and slash pine seedling mortality on recently converted agricultural croplands in northern Florida. In Florida's western panhandle, WFB clearly represent a major threat to the establishment of slash and probably other pines on such sites. WFB appear to be much less a problem in north-central Florida (Madison Co.), possibly due to their flightless character and concomitant migratory inefficiency, as well as geographical differences in agricultural cropping histories, soil types, and/or other unknown factors. WFB were apparently introduced into Okaloosa Co. (west Florida) in the 1930s (Young et al. 1950). In Madison Co., other pests including MP and possibly other root-feeding insects (e.g., WG, and/or others) become increasingly important as apparent contributors to first-year pine seedling mortality.

WFB feed on more than 300 species of plants (including trees) and show a particular preference for leguminous agri-

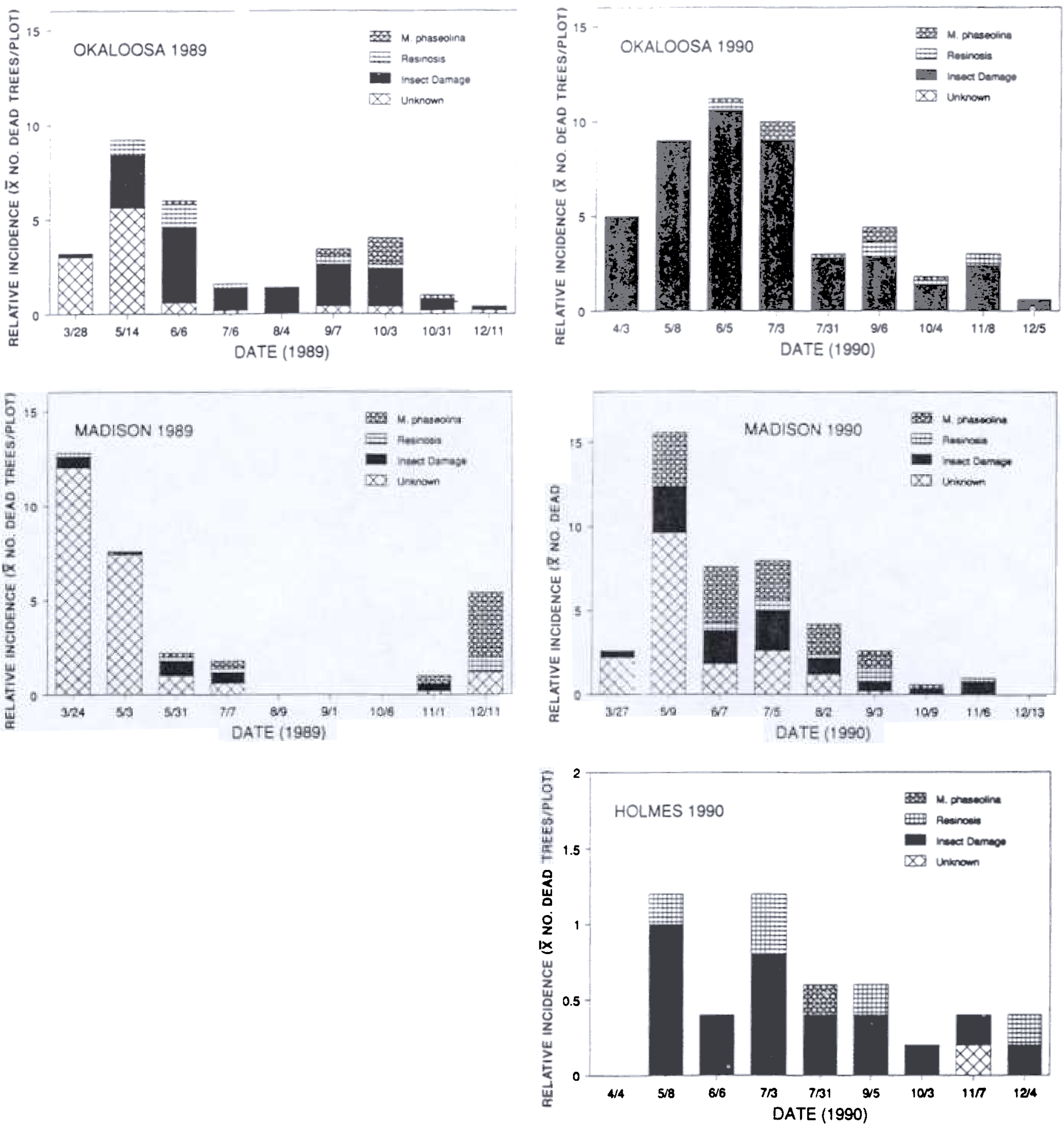

Figure 4. Relative incidence of slash pine seedling mortality (checks only) and associated insect feeding damage, microsclerotia of *Macrophomina phaseolina*, and root or stem resinosis over time on converted agricultural croplands in northern Florida. Vertical scale indicates mean number of dead and dying seedlings removed per plot on dates specified; total bar heights sometimes slightly higher than actual number of dead and dying trees since more than one pest indicator occurred on some trees.

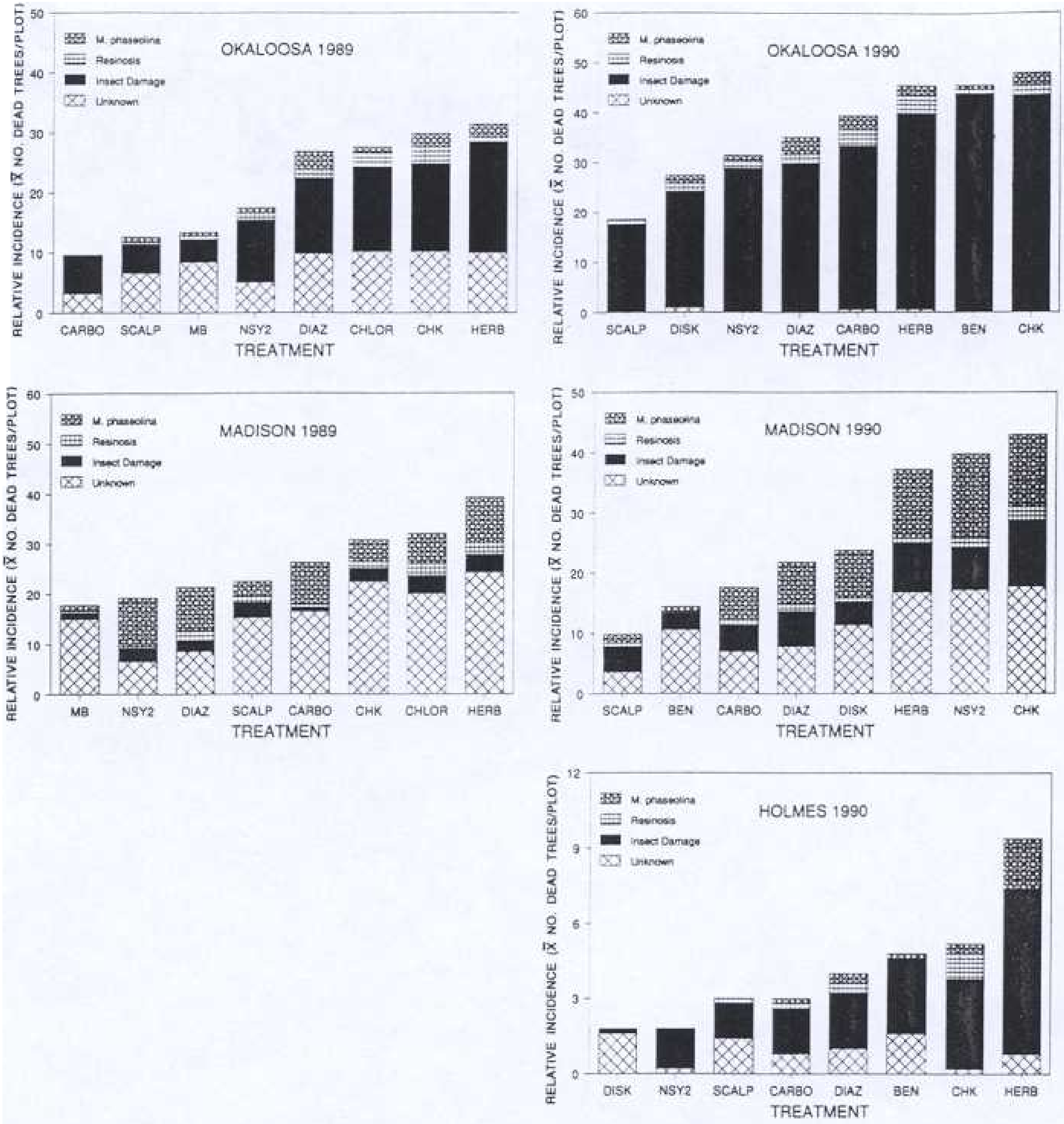

Figure 5. Relative incidence of slash pine seedling mortality and associated insect feeding damage, microsclerotia of *Macrophomina phaseolina*, and root or stem resinosis by treatment on converted agricultural croplands in northern Florida. Vertical scale indicates mean number of dead and dying seedlings removed per plot through the first year following outplanting; total bar heights sometimes slightly higher than actual number of dead and dying trees since more than one pest indicator occurred on some trees.

cultural crops (Young et al. 1950). Filer et al. (1977) mentioned WFB as pests of sycamore (*Platanus occidentalis* L.) in the gulf coastal plain, and Price (1988) described WFB damage on pine seedlings in Georgia. Dixon (1982—unpublished) attributed the failure of a slash pine plantation on a former peanut field in Jackson Co. Florida to root damage resulting from feeding activity of WFB larvae. However, it appears that the potential of WFB as pests of southern pine seedlings was not fully recognized until the advent of the CRP. Mitchell et al. (1991) recently reported WFB damage to loblolly pine (*Pinus taeda* L.) on converted agricultural fields in Georgia, and in certain areas of Florida's western panhandle we have confirmed that more than 90% of the mortality in several "failed" CRP plantations was due to feeding by

WFB larvae (authors and Florida Division of Forestry Co. foresters—unpublished). We believe these insects merit increased attention as pests of pines.

MP is a well-documented pathogen of pines in forest tree nurseries (Hodges 1962, Reuveni and Madar 1985, McCain and Scharpf 1989, Smith et al. 1989), and it has been reported in association with pine mortality in various field situations (Smalley and Scheer 1963). It is typically a problem in pine nurseries when seedbed soils are hot and dry and seedlings are water-stressed (Hodges 1962, Reuveni and Madar 1985), a habit in keeping with its well-documented, stress-related pathogen biology (Dhingra and Sinclair 1978, Watkins 1981, McDonald and Mehan 1984, Wylie 1989). Pine seedlings must necessarily be regarded as under some type of stress (water stress, herbaceous weed competition, physiological stress, etc.) during the period of "establishment" following outplanting. Proportionally, MP occurred on 4–5 times more dead and dying seedlings in Madison Co., than in Okaloosa and Holmes counties, despite higher populations of the pathogen in Okaloosa Co. soils in both study years. This is consistent with a water-stress disease hypothesis since the Madison Co. study site was much more sandy and drought-vulnerable than the other two sites. In both study years, Madison Co. received far less rainfall than Okaloosa Co.; 1075 and 1200 mm compared to 2100 and 1600 mm, respectively. Holmes Co. received the lowest total rainfall of all sites in 1990, but rainfall through midsummer at this location totaled 425 mm, considerably more than the 250 mm received during the same period at Madison Co.

The pitch canker fungus (FS) apparently plays an insignificant role in the first-year mortality of pines on converted agricultural croplands. We isolated FS from dead and dying seedlings very infrequently (1989), and in neither of our 2 study years (1989, 1990) was resin-soaking typical of seedling pitch canker infections prevalent (only observed on 5–6% of the seedlings examined; comparable to regional data reported by Cordell et al. 1993). In some cases, resin-soaking was associated with factors other than FS (e.g., other *Fusarium* spp., MP, mechanical or insect injury). Mitchell et al. (1991) reported recovery of FS from up to 60% of loblolly pine seedlings on converted agricultural croplands in Georgia. While this figure could reflect differences in pine species, geographical location, isolation techniques, etc., fungus misidentification, and/or the recovery of FS strains not pathogenic to pines (Dwinell and Nelson 1978, Dwinell et al. 1985) are also possibilities. The pitch canker fungus (i.e., strains of FS pathogenic to pines) is not commonly recovered from southeastern U.S. soils, even where inoculum of the fungus might expectedly be abundant, e.g., beneath severely infected trees (Dwinell and Barrows 1978). Also, recovery of the pitch canker fungus from 5–10% of seedlings of even the generally more susceptible slash pine (Dwinell 1978), possibly due to seed and/or seedling infection and subsequent nursery-to-field carryover (Dixon et al. 1991), would be considered relatively high (L.D. Dwinell and G.M. Blakeslee, pers. comm., E.L. Barnard—unpublished). Mitchell et al. (1991) did not report the presence or absence of FS in their study soils, nor did they discuss the presence or absence of root or stem resin-soaking typical of seedling pitch canker infections.

The presence of *F. oxysporum* and *F. solani* on the roots of dead and dying slash pine seedlings (1989 isolations) may reflect only saprophytic colonization of root tissues. However, the relative prevalence of these organisms in the soil and on the seedlings evaluated, together with their reported pathogenicities (Hodges 1962, Johnson et al. 1989) provide an impetus for further study.

The role of plant parasitic nematodes in Florida's agricultural cropland-pine mortality syndrome remains undetermined. Overall, the nematode populations documented in our study are not regarded as unusual for Florida agricultural soils (P. Lehman and R. Inserra, Florida Dept. of Agric. & Cons. Services—pers. comm.) and are generally comparable to those reported by Sharma et al. (1989) from CRP plantations in Georgia. Sharma et al. (1989) found ring (*Criconemella* spp.) and dagger (*Xiphinema* spp.) nematodes to be the most commonly occurring genera in their survey. These two genera were also among those most commonly encountered in our study, and were dominant in our Madison Co. soils. Mitchell et al. (1991) reported relatively high recoveries of ring and dagger nematodes, as well as relatively high numbers of spiral and lesion nematodes from CRP sites in Georgia. The possibility of direct nematode-induced root damage and/or nematode-fungus interactions in root disease complexes should not be overlooked (Hodges 1962, Reuhle 1973).

A substantial proportion of the seedling mortality observed in our study (Figures 4 and 5), especially that occurring through the month of April (Figure 4), could not be confidently related to the occurrence or activity of any particular pest. We do not regard this as unusual. A certain amount of post-outplant mortality is expected due to transplant injury and/or shock, etc., which may be exacerbated by Florida's frequently droughty springs. Moisture stress may have played an especially important role in the early seedling mortality observed on the sandy and drought-vulnerable Madison Co. sites. In 1989, only 275 mm of rainfall were recorded in Madison Co. from January through May. More than 475 mm were recorded at the same location for June through August. In 1990, rainfall at Madison Co. was generally distributed more evenly throughout the year, although less than 25 mm was received at this location in both June and August. Rainfall at the Okaloosa and Holmes Co. sites was more evenly distributed throughout the two growing seasons.

Chemical phytotoxicity could have been a factor in the performance of seedlings within certain treatments (e.g., CARBO, BEN, HERB) in our study. However, we do not regard this possibility as likely. All chemical treatments we employed were consistent with currently accepted and practiced operational procedures and/or applied at rates at or below those recommended for such uses. Further and extensive research would be required to elucidate all possible subtleties with respect to pesticidal phytotoxicity. Nonetheless, several of the observed effects of pesticides employed in our study warrant mention. For example, CARBO and BEN root dips showed some efficacy with respect to protecting seedlings from soilborne insects and root-infecting fungi, respectively. In 1989, CARBO-treated seedlings exhibited the highest survival among all treatments in Okaloosa Co. (Figures 3 and 5). In 1990, CARBO-treated seedlings had the lowest incidence (3%) of insect feeding injury among all treatments in Madison Co. Proportionally, MP and root or stem resin-soaking were detected, respectively, on 10 and 5 times fewer BEN-treated seedlings than check seedlings across all three study sites in 1990. Indeed, with only one exception (MP on one seedling in July, Madison Co.), neither MP nor root or stem resin-soaking was detected on BEN treated seedlings until the September–October collection dates. However, the high survival, yet poor growth, of CARBO and BEN treated seedings in Madison Co. in 1990 (Table 2) suggests that pesticidal protection of roots from soilborne pests can increase survival, but fail to mitigate the effects of intense weed competition. Further, superior early season survival of CARBO treated seedlings at Okaloosa Co. (1990), followed by rapid seedling mortality during mid- to late summer (Figure 3), suggests decreasing pesticidal efficacy in some situations due possibly to material breakdown or dilution. Alternatively, WFB populations and/or activity on this site may have been overwhelming (Figure 5). Accordingly, limited pesticidal efficacy notwithstanding, treatment inconsistency, the overall superiority of scalping, and the safety and logistical constraints associated with insecticide and/or fungicide root dips render such treatments less appealing than scalping.

The poor overall performance of seedlings on HERB-treated plots (Table 2, Figures 3 and 5) was unexpected. We anticipated improved seedling performance due to reduced herbaceous weed competition. Instead, seedlings on HERB-treated plots were among the poorest performers on all five sites. Similar observations on other agricultural croplands have been reported to us by others in both Florida and Georgia (Mary Kay Hicks, Florida Division of Forestry, and Terry Price, Georgia For. Comm.—pers. comm.). In addition, HERB-treated seedlings in Okaloosa Co. (1989) and Holmes Co. (1990) had the highest level of WFB feeding damage (Figure 5), suggesting that where these insects are prevalent, the elimination of herbaceous weeds, without the apparent mechanical and/or biological advantages of scalping, may exacerbate larval feeding on the roots of the remaining pines. A suggestion to this effect was published by Mitchell et al. (1991). They also hypothesized that "this risk could be reduced by using band applications of herbicides, leaving vegetation for the insects to feed on between pine rows." Our data from herbicide band applications, representative of standard practices in pine plantings on converted agricultural croplands southwide, do not validate such a hypothesis.

Our MB treatment (1989) was employed solely as a gauge to observe seedling performance in the absence of pressures from pests in general, e.g., insects, fungi, weeds, nematodes, etc. Although seedling performance was very good in MB treated soils, we are not promoting MB as a viable management option. The practicality, safety, and economics of this treatment are likely to prove prohibitive.

The relatively good performance of seedlings from NSY2 as compared to that of CHK trees in our 1989 plots suggests that seedling quality and vigor are key ingredients for successful plantation establishment on converted agricultural croplands. Although not quantified in 1989, it appeared that there were fewer cull seedlings in the NSY2 lot than there were in the checks. In 1990, seedlings from NSY2 had larger stem diameters (mean = 5 as compared to 4 mm), a more desirable shoot/root ratio (4.6 as compared to 5.9), and fewer "culls" (only 8% as compared to 23% of seedlings with stem diameters <3 mm) than check seedlings. However, field performance of seedlings from the two nurseries did not materially differ in 1990. Apparently, seedling quality alone does not afford an adequate guarantee of plantation success on agricultural croplands such as those evaluated in our study.

Overall, scalping provided the most dramatic and consistent improvement in seedling performance across all five study sites. Shoulders (1958) reported similar results (survival only) for scalping on dry grassy sites in Louisiana with loblolly, longleaf (*P. palustris* Mill.), and slash pines. He attributed improved survival to better planting and reduced weed competition. Scalping is economically, logistically, and ecologically sound if performed with due precautions (e.g., along contours) on sites otherwise amenable to this practice; sites with excessive slopes and/or fine textured soils could pose erosion problems if scalped indiscriminately. Scalping has been routinely employed for silvicultural purposes on pasturelands and hayfields in Florida for many years with good success, and preliminary comparative statistics (authors—unpublished) give this procedure high performance

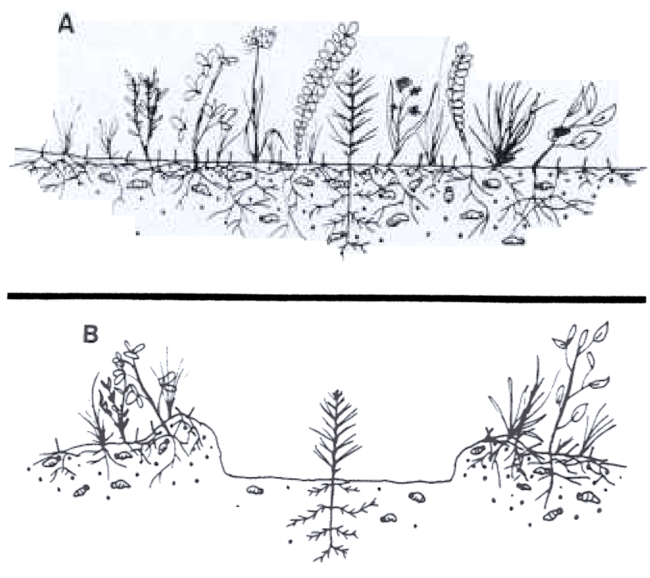

Figure 6. A simplified schematic illustrating benefits of scalping agricultural croplands before planting pines. (A) Pine seedling planted on unscalped soil. Note weed competition and challenge to root system by insect larvae (small grubs) and propagules of the charcoal root rot fungus (black dots), *Macrophomina phaseolina*. (B) Pine seedling planted in scalped furrow. Note reduced weed competition and reduced pressure from insect larvae and fungus propagules. Most insect larvae and fungus propagules have been displaced out of the seedling rhizosphere by the scalping process.

ratings when compared to other site preparation practices. We believe improved seedling performance is the combined result of reduced weed competition, improved moisture relations, reduced pressure from certain root pathogens (Figure 2), reduced insect damage (Figure 5), and probably improved planting efficacy (e.g., facilitated operation of seedling planters on soil surfaces cleared of stubble and organic debris) (Figure 6). Scalping should be evaluated on similar sites across the South where pine seedling mortality is a problem and the involvement of soilborne pests is either documented or likely.

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